Thermochemistry exam.
IB11

Name:

Useful information

Ethanol: ΔH_{comb} = -1236 kJ/mol
Octane: molar mass: 114 g/mol. Density: 703. ΔH_{comb} = -5400 kJ/mol
Aluminium: Heat capacity: 24.2 J/mol·K. Density: 2700 . Atomic weight (approx.): 27 amu
Iron: melting point: 1811 K. ΔH_{fusion}=13.81 KJ/mol. Heat capacity: 25.1 J/mol·K
Methanol: ΔH_{comb}= -676.5 KJ/mol
Formaldehyde: ΔH_{comb} = -520 KJ/mol
Water: ΔH_{form} = -242 KJ/mol

1. High-pressure cleaning systems usually involve an electric motor to drive a piston pump and, if the water needs to be heated up, a boiler and a heat exchanger to do so.
The town of Tudela made a public project offer to build a vehicle to clean the streets, and since hot pressurized water would be used, they emphasized that a major consideration would be energy efficiency.
In the nearby village of Cintruénigo, the chief engineer and owner of a small company called Dugar, after some creative thinking, presented an original solution: instead of using an electric motor, he bought a Daewoo 1.6 gasoline engine, drilled through the casing and streamed water as cooling agent (heating up the water). The motor itself drove the piston pump and the exhaust fumes were directed through a flat heat exchanger to further heat up the water.
The resulting device was capable of heating 100g of water per second from 5 to 50ºC, and did so consuming only 4.4 litres per hour of gasoline (for this exercise we can consider it octane).
(The efficiency boost was achieved mostly by using the exhaust gases, although this meant that the heat exchanger had to be periodically disassembled and the accumulated soot scraped off with a sharp spatula).
a) Calculate how much heat is transferred to the water every second. [2]

b) Calculate how many moles per second of octane the engine consumes. [1]

c) Calculate the energy efficiency of the device.[2]

2. a) Calculate how much energy is needed to heat up a hundred kilograms of aluminium from 10 to 45 ºC [1]

b) What requires more energy to be warmed up, one cubic meter of aluminium or one of water? Explain your answer. [2]

2. Engineers at Barcelona University have built a prototype of parabolic mirror that can be used to melt iron.
Initial tests at 15% power (that is, with only 15% of the mirror exposed to sunlight) show that the mirror is capable of melting 19g of room-temperature iron per second.
Assuming that the initial temperature of the iron is 25 ºC (Spain, right?)
a) Calculate the full power of the mirror. [2]

The engineers at Umeå university, captivated by the might of the Catalonian mirror, decided to build their own device, but due to the longer trajectory of sunlight through the atmosphere, the mirror has a power of 9500W.
A test is run, attempting to melt a block of 10kg of iron that is initially at 10 ºC.
Given that the sun is only unblocked by the clouds for 15 minutes:
b) Will all the iron melt? If not, how much will melt? [2]

3. The decomposition of methanol into formaldehyde and hydrogen

$$CH_3\text{-}OH \rightarrow H_2CO + H_2$$

has been proposed as a way to safely store hydrogen, since methanol is much less dangerous and doesn't require pressurized container.

Calculate the variation of enthalpy associated with this reaction. [2]

4. (HL) Use the data in this table to calculate the lattice enthalpy of BaF_2 [3]
Optional: draw a diagram [1]
The lattice enthalpy is negative, but we get a positive number and it also appears positive in the book. Explain why this is referring to the definition. [1]

	$/ kJ\,mol^{-1}$
ΔH_{at} [Ba(s)]	176
ΔH_{at} [F_2(g)]	79
first ionisation energy (Ba)	502
second ionisation energy (Ba)	966
first electron affinity (F)	−348
ΔH_f (BaF_2(s))	−1201

5. Use the data in the table to calculate the enthalpy change of the reaction in exercise 3. [2]
Explain why it is not the same value as obtained using Hess' law [1]

Bond	Bond enthalpy $/ kJ\,mol^{-1}$	Bond	Bond enthalpy $/ kJ\,mol^{-1}$	Bond	Bond enthalpy $/ kJ\,mol^{-1}$	Bond	Bond enthalpy $/ kJ\,mol^{-1}$
H–H	436	C–H	412	O–O	146	C–O	360
C–C	348	Si–H	318	O=O	496	C=O	743
C=C	612	N–H	388	Si–O	374	C≡O	1070
C≡C	837	P–H	322	F–F	158	C–N	305
Si–Si	226	O–H	463	Cl–Cl	242	C=N	613
N–N	163	S–H	338	Br–Br	193	C≡N	890
N=N	409	F–H	562	I–I	151	C–F	484
N≡N	944	Cl–H	431	N–Cl	200	C–Cl	338
P–P	172	Br–H	366	Si–F	590	C–Br	276
S–S	264	I–H	299	N–F	278	C–I	238

6 (HL). The reaction of formation of urea from ammonia and carbon dioxide:

$2NH_3 + CO_2 \rightarrow NH_2CONH_2 + H_2O$ $\Delta H = -133.52$ KJ/mol

has a entropy variation of -356 J/K

a) Is it spontaneous at 25ºC? [2]

b) Will it be more spontaneous at 100ºC? [2]

c) At what temperature will it "stop being spontaneous"? Is it spontaneous below that themperature or above it? [2]