1. A reservoir of 50 l is filled once with octane (liquid) and once with hydrogen (to a pressure of 1 atm). Assume the ideal gass law for the calculations.
a) In which case is the combustion (complete reaction with O_2) of the entire content of the reservoir delivering more energy at 25 °C.
b) What H_2 pressure is needed so that the combustion of it provides the same amount of energy as octane?
c) For which if the questions a) and b) is the assumption of ideal gas behavior justified?

density octane: 0.703 g/mL
C_8H_{18}(l) liquid −250.2 kJ mol^{-1}
H_2O(l) liquid water −285.83 kJ·mol^{-1}
H_2O(g)water vapor −241.82 kJ·mol^{-1}
CO_2(g)carbon dioxide gas −393.51 kJ·mol^{-1}

Balanced equation:

$$C_8H_{18}(l) + \frac{25}{2}\ O_2(g) \rightarrow 8\ CO_2\ (g) + 9\ H_2O\ (g)$$

$$\Delta H_C^{\circ} = 8 \cdot \Delta H^{\circ}(CO_2) + 9 \cdot \Delta H^{\circ}(H_2O) - \Delta H^{\circ}(C_8H_{18})$$

$$\Delta H_C^{\circ} = 8 \cdot (-393.51\ kJ \cdot mol^{-1}) + 9 * (-285.83\ kJ \cdot mol^{-1}) - (-250.2\ kJmol^{-1})$$

$$\Delta H_C^{\circ} = -5720.55\ kJ \cdot mol^{-1} + 250.2\ kJ \cdot mol^{-1} = \mathbf{-5470.35\ kJ \cdot mol^{-1}}$$

Volume of reservoir = 50.0 L = 50 000 mL.
Mass of octane = density × volume = 0.703 g/mL × 50 000 mL = **35 150 g**.
Moles of octane = 35 150 g / 114.2285 g·mol^{-1} = **≈307.7 mol**.
Energy released by combusting all octane = moles × ΔH^c
= 307.7 mol × 5470.3 kJ·mol^{-1} ≈ **1.683×10^6 kJ** = **1.68×10^9 J**.

H_2 in 50 L at 1 atm, 25 °C (ideal gas):
n = PV/(RT) = (1.0 atm × 50.0 L) / (0.082057 L·atm·mol^{-1}·K^{-1} × 298.15 K) ≈ **2.044 mol**.
Energy from combusting that H_2 = 2.044 mol × 285.83 kJ·mol^{-1} ≈ **584 kJ** (≈5.84×10^5 J).
Conclusion: 50 L octane ≈ **1.68×10^6 kJ**, while 50 L H_2 @1 atm ≈ **5.84×10^2 kJ**.
Octane provides **~2.9×10^3 times more** energy in the same 50 L.

b) Pressure of H_2 required to give same energy:
Required moles of H_2 = E_octane / (285.83 kJ·mol^{-1}) ≈ 1.683×10^6 kJ / 285.83 kJ·mol^{-1} ≈
5.889×10^3 mol.

Using ideal gas law for 50 L at 298.15 K: P = nRT/V = (5889.17 mol × 0.082057 L·atm·mol^{-1}·K^{-1} × 298.15 K) / 50.0 L ≈ **2882 atm ≈ 292 MPa**.

c) The assumption of ideal gas behaviour is only valid in case a).

2. What properties of hydrogen argue against its classification as a Group 17 element?
A) Hydrogen has no *p*-electrons and has a very low electron affinity.
B) Hydrogen is more metallic.
C) Hydrogen forms two bonds with other elements, unlike one bond for Group 17.
D) Hydrogen is inert like a noble gas.

The metallic character of hydrogen is very low, and it does not form two bonds with other elements. Hydrogen is not inert like a noble gas. Thus, B, C, and D can be excluded. In addition, Hydrogen has no p-electrons and a low electron affinity.

3. What is the balanced chemical equation for the reaction of potassium and water?
A) $K(s) + 2\ H_2O(l) \rightarrow KO_2(s) + 2\ H_2(g)$
B) $2\ K(s) + H_2O(l) \rightarrow K_2O + H_2(g)$
C) $2\ K(s) + 2\ H_2O(l) \rightarrow 2\ KOH(aq) + H_2(g)$
D) $K(s) + 2\ H_2O(l) \rightarrow KO(s) + H_2(g)$

Alkali metals react with water to form hydrogen gas and metal hydroxide. Alkaline earth metals also react with water to produce hydrogen gas and metal hydroxides, but their reactions are less vigorous than those of alkali metals. Iron (Fe) and Zinc (Zn) are less reactive and only react with water steam to form metal oxides. Copper (Cu) and gold (Au) do not react with water under normal conditions.

4. What is the balanced chemical equation for the reaction of lime and water to form slaked lime?
A) $CaCO_3(s) + H_2O(l) \rightarrow Ca(s) + H_3O^+(aq) + CO_2(g)$
B) $CaCO_3(s) + H_2O(l) \rightarrow CaO(s) + H_2CO_3(aq)$
C) $CaO(s) + 2\ H_2O(l) \rightarrow CaCO_3(s) + 2\ H_2(g)$
D) $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(s)$

Calcium hydroxide is commonly known as slaked lime because the thirst of lime for water has been quenched (slaked).
$Ca(OH)_2$(aq)

5. What do chalk, marble, and limestone all have in common?
A) They are all common terms for the same silicon-based mineral.
B) They are all silicates.
C) They are all non-crystalline.
D) They are all calcium carbonate.

The most common silicon-based minerals are quartz (formed from SiO_2), feldspar, and mica (silicate minerals). However, chalk, marble, and limestone are formed from calcium carbonate. They all react with acids to form a salt, water, and carbon dioxide gas.

6. Which oxidation numbers can nitrogen have in its oxides?
A) +1 and +3
B) +1, +3, and +5
C) +2, +4, and +5
D) +1, +2, +3, +4, and +5

N_2O	+1
NO	+2
N_2O_3	+3
N_2O_4	+4
N_2O_5	+5

7. Tetraphosphorus decoxide reacts with water to produce phosphoric acid. What is the balanced reaction for this process?
A) $P_4 + 3\ O_2 + 6\ H_2O \rightarrow 4\ H_3PO_4$
B) $P_2O_5 + 3\ H_2O \rightarrow 2\ H_3PO_3$
C) $P_4O_{10} + 6\ H_2O \rightarrow 4\ H_3PO_4$
D) $P_4O_{10} + 4\ H_2O \rightarrow 4\ H_3PO_3$

Tetraphsophorus decoxide is only found in answer C) and D).
Phosphoric acid is H_3PO_4. You need to learn this by heart, as phosphate (PO_4^{3-}) is relevant for biochemical processes.
In addition, the reaction in D) is not balanced.

8. What is the balanced chemical equation for the reaction of sulfur dioxide and water?

A) $SO_2(g) + H_2O(l) \rightarrow S(s) + O_2(g) + H_2O(l)$
B) $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$
C) $SO_2(g) + H_2O(l) \rightarrow SO_3(g) + H_2(g)$
D) $SO_2(g) + 2\ H_2O(l) \rightarrow H_2SO_4(aq) + 2\ H_2(g)$

A) Water is found on both sides of the equation. So water is not involved in the reaction.

C +D) Can be excluded because H_2O is a very weak oxidation reagent. In both cases, the oxidation number of sulfur increases from +4 to +6, which requires a strong oxidation reagent.

9. Write the chemical equation for the reaction between lithium and oxygen.
$4\ Li\ (s) + O_2\ (g) \rightarrow 2\ Li_2O\ (s)$

10. Write the chemical equation for the reaction between potassium and oxygen.
$K\ (s) + O_2\ (g) \rightarrow KO_2\ (s)$

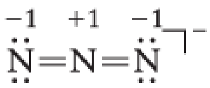
The principal product of the reaction of the alkali metals with oxygen varies down the group. Lithium forms mainly Li_2O. Sodium forms mainly very pale yellow Na_2O_2, which contains the perioxide ion, O_2^{2-}. Potassium forms mainly KO_2, which contains the superoxide ion, O_2^{-}.

11. Like KO_2, cesium superoxide, CsO_2, can be used to remove exhaled CO_2 and generate oxygen from water. Explain why KO_2 is preferred over CsO_2 for this purpose on spacecraft.

The molar mass of KO_2 is less than CsO_2 so a spacecraft would be able to carry more KO_2 than CsO_2.

12. (a) Draw the Lewis structure for the azide ion and assign formal charges to the atoms. (b) You will find it possible to write a number of Lewis structures. Which is likely to make the biggest contribution to the resonance? (c) Predict the shape of the ion and its polarity.

A)

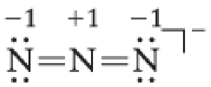


B) This is the most stable structure.

C) This is a linear molecule and symmetrical or nonpolar.

Short Answers

1. a) octane 1.683×10^6 kJ; H_2=1.68×10^6 kJ
   b) 2882 atm
   c) a
2. A
3. C
4. D
5. D
6. D
7. C
8. B
9. 4 Li (s) + O_2 (g) $\rightarrow$ 2 Li_2O (s)
10. K (s) + O_2 (g) $\rightarrow$ KO_2 (s)
11. Less weight
12. A)

    B) structure above is the most stable

    C) linear, non polar