Year 12 Science: Energy changes in reactions

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Is ice melting endothermic or exothermic?

2. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, $\Delta rH = -890$ kJ mol^{-1}. How much energy is released by burning 4.00 g of methane? $M(CH_4) = 16.0$ g mol^{-1}.

3. Using the same equation, what mass of methane must burn to release 1780 kJ?

4. Use the bond enthalpy table to calculate ΔrH for $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$.

5. $N_2 + 3H_2 \rightarrow 2NH_3$ has $\Delta rH = -92$ kJ mol^{-1}. What is ΔrH for $2NH_3 \rightarrow N_2 + 3H_2$?

Exam-style question: hydrogen as a fuel

Hydrogen can power vehicles, either burned in an engine or in a fuel cell, and the only product is water. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$, $\Delta rH = -572$ kJ mol^{-1}. $M(H_2) = 2.0$ g mol^{-1}.

6. State whether the reaction is exothermic or endothermic, and explain your choice in terms of bonds.

7. Calculate the energy released when 1.00 kg of hydrogen reacts.

8. Calculate the mass of hydrogen that must react to release 2000 kJ.

9. When the water forms as a gas, $\Delta rH = -484$ kJ mol^{-1}. Use this and H–H = 436 and O=O = 498 kJ mol^{-1} to calculate the average O–H bond enthalpy.

10. Explain why ΔrH is more negative when liquid water forms than when water vapour forms.

Fix the mistake

11. Correct this statement: "Breaking bonds releases energy, which is why fuels give out heat."

12. Correct this statement: "ΔrH = bonds formed − bonds broken."

13. Correct this statement: "For $N_2 + 3H_2 \rightarrow 2NH_3$, bonds formed = 3 × N–H."

14. Correct this statement: "An endothermic reaction feels hot, because it takes in heat."

Answer key (for parents and tutors)

1. Is ice melting endothermic or exothermic?
   Endothermic: energy is absorbed to overcome the attractions between water molecules.
2. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, $\Delta rH = -890$ kJ mol^{-1}. How much energy is released by burning 4.00 g of methane? M(CH_4) = 16.0 g mol^{-1}.
   n = 4.00 ÷ 16.0 = 0.250 mol; energy = 0.250 × 890 = 222.5 kJ, so about 223 kJ released (ΔH = −223 kJ).
3. Using the same equation, what mass of methane must burn to release 1780 kJ?
   n = 1780 ÷ 890 = 2.00 mol; m = 2.00 × 16.0 = 32.0 g.
4. Use the bond enthalpy table to calculate ΔrH for $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$.
   Broken: 436 + 190 = 626 kJ; formed: 2 × 370 = 740 kJ; ΔrH = 626 − 740 = −114 kJ mol^{-1}.
5. $N_2 + 3H_2 \rightarrow 2NH_3$ has $\Delta rH = -92$ kJ mol^{-1}. What is ΔrH for $2NH_3 \rightarrow N_2 + 3H_2$?
   Reversing the equation changes the sign: ΔrH = +92 kJ mol^{-1}.
6. State whether the reaction is exothermic or endothermic, and explain your choice in terms of bonds.
   Exothermic: ΔrH is negative, because more energy is released forming the O–H bonds than is absorbed breaking the H–H and O=O bonds (Achieved for exothermic with a reason).
7. Calculate the energy released when 1.00 kg of hydrogen reacts.
   n(H_2) = 1000 ÷ 2.0 = 500 mol; 2 mol H_2 releases 572 kJ, so 1 mol releases 286 kJ; energy = 500 × 286 = 143 000 kJ released, ΔH = −1.43 × 10^5 kJ (Merit for the answer with unit).
8. Calculate the mass of hydrogen that must react to release 2000 kJ.
   n(H_2) = 2000 ÷ 286 = 6.99 mol; m = 6.99 × 2.0 = 14.0 g (Excellence needs both 2 and 3 correct).
9. When the water forms as a gas, $\Delta rH = -484$ kJ mol^{-1}. Use this and H–H = 436 and O=O = 498 kJ mol^{-1} to calculate the average O–H bond enthalpy.
   Broken: 2 × 436 + 498 = 1370 kJ; formed: 4 × (O–H), since 2 H_2O have 4 O–H bonds; −484 = 1370 − 4(O–H); 4(O–H) = 1854; O–H = 463.5, about 464 kJ mol^{-1} (Excellence for the correct answer with unit; Merit for the right process with one slip).
10. Explain why ΔrH is more negative when liquid water forms than when water vapour forms.
    Excellence: going from 2 mol of water vapour to 2 mol of liquid forms attractions between water molecules, which releases energy, so condensing is exothermic. That extra 572 − 484 = 88 kJ is released on top of the energy from the reaction, making ΔrH more negative.
11. Correct this statement: "Breaking bonds releases energy, which is why fuels give out heat."
    Breaking bonds always absorbs energy; fuels release energy because forming the bonds in CO_2 and H_2O releases more.
12. Correct this statement: "ΔrH = bonds formed − bonds broken."
    ΔrH = bonds broken − bonds formed, so a reaction that forms stronger bonds gets a negative ΔrH.
13. Correct this statement: "For $N_2 + 3H_2 \rightarrow 2NH_3$, bonds formed = 3 × N–H."
    Two NH_3 molecules each have three N–H bonds, so 6 × N–H are formed: multiply by the coefficient.
14. Correct this statement: "An endothermic reaction feels hot, because it takes in heat."
    It takes energy from the surroundings, so the beaker and your hand feel colder.