1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (270)	109 Mt (278)	110 Ds (281)	111 Rg (282)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (290)	116 Lv (293)	117 Ts (294)	118 Og (294)

58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (266)

Single Bond Energies

	H	C	N	O
H	436			
C	413	346		
N	391	305	163	
O	463	358	201	146

all values are kJ/mol

Multiple Bond Energies (kJ/mol)

C=C 602	C=N 615	C=O 799
C≡C 835	C≡N 887	C≡O 1072
N=N 418	N=O 607	C=S 577
N≡N 945	O=O 498	

water data

$C_{s,\text{ice}} = 2.09$ J/g °C

$C_{s,\text{water}} = 4.184$ J/g °C

$C_{s,\text{steam}} = 2.03$ J/g °C

$\rho_{\text{water}} = 1.00$ g/mL

$\rho_{\text{ice}} = 0.9167$ g/mL

$\Delta H_{\text{fus}} = 334$ J/g

$\Delta H_{\text{vap}} = 2260$ J/g

This exam should have exactly 20 questions. Each question is equally weighted at 5 points each. Bubble in your answer choices on the bubblehseet provided. Your score is based on what you bubble on the bubblesheet and not what is circled on the exam.

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1. A fuel is burned in a combustion reaction. You, safely standing in the surroundings, say, "wow that was hot!" This reaction is...

● a. exothermic

b. endothermic

Explanation: Exothermic reactions release heat. If you feel the heat from the perspective of the surroundings, then the process is exothermic.

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2. A combustion reaction is performed in a bomb calorimeter. The temperature of the water rises from 25.1 °C to 26.9 °C. Which of the following is/are true regarding this process?

I. the combustion reaction is exothermic

II. the combustion reaction is endothermic

III. the combustion reaction releases heat

IV. the heat flow of the calorimeter, q_{cal}, is positive

a. I, II, and IV

● b. I, III, and IV

c. I and IV

d. II and IV

e. I, II, III, and IV

Explanation: For this process, the q_{cal} can be measured to be positive. Flip the sign to get into the perspective of the reaction system. That means that the reaction is exothermic and releases heat. I, III, and IV are correct.

---

3. Consider the following heat capacities for various substances:

$C_{\text{s,lithium}} = 3.58\ \frac{\text{J}}{\text{g}\ ^\circ\text{C}}$ $C_{\text{s,iron}} = 0.450\ \frac{\text{J}}{\text{g}\ ^\circ\text{C}}$
$C_{\text{s,air}} = 1.012\ \frac{\text{J}}{\text{g}\ ^\circ\text{C}}$ $C_{\text{s,helium}} = 5.193\ \frac{\text{J}}{\text{g}\ ^\circ\text{C}}$
$C_{\text{s,mercury}} = 0.140\ \frac{\text{J}}{\text{g}\ ^\circ\text{C}}$ $C_{\text{s,water}} = 4.184\ \frac{\text{J}}{\text{g}\ ^\circ\text{C}}$

Which substance will have the greatest increase in temperature upon the addition of 10 kJ to the same mass of each substance?

a. lithium

b. iron

● c. mercury

d. air

e. water

f. helium

Explanation: The greatest temperature change will be observed in the substance with the lowest specific heat capacity. This is mercury.

---

4. Determine which of the following processes are **endothermic**:

I. a chemical reaction absorbs 44 kJ of heat

II. a cold glass of water freezes

III. silver jewelry is melted

● a. I and III

b. I and II

c. II only

d. I only

e. II and III

Explanation: Statements one and three refer to processes that absorb heat and are therefore endothermic.

---

5. A standard gold bar held by central banks weighs approximately 12.4 kg. What is the minimum amount of energy needed to fully melt a metal bar that is already at its melting point? The heat of fusion for gold is 63.0 J/g.

- a. 781 kJ
- b. 7.82 kJ
- c. 197 kJ
- d. 525 kJ
- e. 5.25 kJ
- f. 982 kJ

Explanation: $q = m\Delta H = (12,400\,\text{g})(63.0\,\text{J/g})$

$q = 781,200\,\text{J} \approx 781\,\text{kJ}$

---

6. A 25 °C cup of water holds approximately 237 g. What is the final temperature of water if this cup of water loses 8.50 kJ?

- a. 16.4° C
- b. 29.8 ° C
- c. 12.5° C
- d. 17.0° C
- e. 8.50° C

Explanation: Use the formula: $q = mC_s\Delta T$

$-8500\,\text{J} = (237\,\text{g})(4.184\,\text{J/g}^\circ\,\text{C})(T_f - 25^\circ\,\text{C})$

---

7. Which of the following will take the most heat to raise 1 °C?

- a. 1.000 L water
- b. 500 mL water
- c. 250 mL water
- d. These will all take the same amount of heat.

Explanation: The more water you have, the more energy you will need to heat it. You can use $q = mC_s\Delta T$ to prove this with each example.

---

8. A 315 g sample of pure methanol liquid is sitting at 0 °C. What is the value of heat flow for the system if this liquid is cooled to its freezing point and then fully frozen? Assume the solid methanol is not cooled beyond its freezing point of -97.6° C. The specific heat capacity for methanol liquid is 2.14 J/g °C. The heat of fusion of methanol is 11.6 J/g and the heat of vaporization is 1100 J/g.

- a. -69.4 kJ
- b. -65.8 kJ
- c. -3.65 kJ
- d. -3.47 kJ
- e. +65.8 kJ
- f. +74.0 kJ
- g. +3.65 kJ

Explanation: Two calculations are necessary here:

$q = mC\Delta T$ and $q = m\Delta H_{\text{trans}}$

$q = (315\,\text{g})(2.14\,\text{J/g})(-97.6^\circ\,\text{C}) = \text{-65,792.12 J}$

$q = (315\ \text{g})(\text{-}11.6\ \text{J/g}) = \text{-3,654 J}$

$q_{\text{total}} = \text{-69,446.12 J} \approx \text{-69.4 kJ}$

---

9. Consider the following balanced chemical equation:

$$2CH_3OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(\ell)$$

If the heat of combustion for methanol is 726 kJ/mol, how much heat is being released in the balanced combustion reaction shown above?

- a. 1452 kJ
- b. 726 kJ
- c. 1089 kJ
- d. 484 kJ

Explanation: Account for the amount:

1452 kJ = 2 mol × 726 kJ/mol

---

10. Consider the following balanced chemical equation:

$$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$$

How much heat is released when 32.7 g of butane are combusted? ΔH for the balanced reaction is equal to -4438.4 kJ/mol rxn. The molar mass of butane is 58.12 g/mol.

●a. 1249 kJ

b. 0.562 kJ

c. 4494 kJ

d. 2497 kJ

e. 76.47 kJ

f. 135.7 kJ

Explanation: 32.7 g butane = 0.56262904335 mol butane. This gives you the ability to run 0.56262904335/2 reactions.

$0.56262904335/2 \times 4438.4 = 1248.5863730$ kJ

---

11. A simple dissolution reaction is performed in a coffee cup calorimeter. When 5.01 g NaCl is placed in 350 mL water, the temperature decreases by 0.227 °C. What is the heat of the dissolution reaction, q_{sys}?

●a. +332 J

b. -332 J

c. +398 J

d. -398 J

e. +4.75 J

f. -4.75 J

Explanation: Solve for q_{cal} and then flip the sign for q_{sys}.

$q = (350\,\text{g})(4.184\,\text{J/g}\,^\circ\text{C})(-0.227\,^\circ\text{C})$

q = -332 J

Flip the sign to get back to the system to get +332 J.

---

12. When 0.432 g of a hydrocarbon fuel are combusted in a bomb calorimeter filled with 1.002 L water, a temperature increase of 0.991 °C is measured. What is the ΔH of the fuel in kJ/g? The heat capacity of the calorimeter hardware is equal to 2.04 kJ/ °C.

●a. -14.3 kJ/g

b. -6.18 kJ/g

c. +6.18 kJ/g

d. +3/18 kJ/g

e. -8.83 kJ/g

f. -1.79 kJ/g

Explanation: Use the equation $q = mC\Delta T + C\Delta T$

$6.1762... = (1002)(4.184 \times 10^{-3})(0.991) + (2.04)(0.991)$

Flip the sign to get into the system: -6.1762 kJ

Normalize for kJ/g: -6.1762 kJ/ 0.432 g = -14.3 kJ/g

---

13. Use bond energy data to determine the ΔH of the following balanced chemical equation:

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

●a. -93 kJ

b. +93 kJ

c. -990 kJ

d. +990 kJ

e. -620 kJ

f. 463 kJ

Explanation: Reactant side = N-N triple bond and 3 H-H single bonds. Product side 6 N-H single bonds.

Reactants = 945 + 3(436) kJ

Products = 6(391) kJ

Reactants - Products = -93 kJ

---

14. Which of the following is true regarding combustible fuels?

●a. The chemical reaction releases heat because the products are lower in energy than the reactants.

b. The chemical reaction absorbs heat because the products are lower in energy than the reactants.

c. The chemical reaction releases heat because the reactants are lower in energy than the products.

d. The chemical reaction absorbs heat because the reactants are lower in energy than the products.

e. The chemical reaction does not absorb or release heat because the products and reactants are equal in energy.

Explanation: The driving force behind burning a fuel is the fact that the chemical reaction releases heat because the products are lower in energy than the reactants.

---

15. Consider the following heats of combustion for three fuel sources:

ΔH MTBE, 88.15 g/mol: 3,362.0 kJ/mol

ΔH Methane, 16.04 g/mol: 803.60 kJ/mol

ΔH Ethanol, 46.07 g/mol: 1234.7 kJ/mol

Which of these fuels is more efficient **per gram**?

●a. Methane

b. MTBE

c. They are equally efficient in kJ/g.

d. Ethanol

Explanation: Convert the kJ/mol value into kJ/g for each and compare:

MTBE: 38 kJ/g = (3,362.0 kJ/mol)/(88.15 g/mol)

Methane: 50.1 kJ/g = (803.60 kJ/mol)/(16.04 g/mol)

Ethanol: 27 kJ/g = (1234.7 kJ/mol)/(46.07 g/mol)

---

16. Asphalt is made from the largest carbon chains separated out in the crude oil refining process. In which portion of the distillation tower will you separate out these hydrocarbons?

●a. the bottom

b. the top

c. the middle

d. equally dispersed throughout the distillation tower

Explanation: Heavy chains remain at the lower portions of the distillation tower.

---

17. An ice cube is heated from -15 °C to steam at 115 °C. If you use a heating curve to solve for the total heat required for this process, how many unique heat calculations are necessary?

●a. 5

b. 6

c. 4

d. 3

e. 8

Explanation: You heat the ice to the freezing point (1), melt the ice (2), heat the ice to the boiling point (3), boil the water (4), and then heat the steam to the final temperature (5).

---

18. Select each phase change that requires heat flow into the system:

I. freezing

II. fusion

III. vaporization

IV. condensation

a. I, II, and IV

b. I, III, and IV

c. I and IV

d. II and IV

e. I, II, III, and IV

●f. II and III

Explanation: Freezing and condensation are exothermic. Fusion and vaporization are endothermic.

---

19. Suppose you refined a large hydrocarbon sample and want to make more money out of your excessively large carbon chains. Which process will allow you to make a specific shorter carbon-based fuel?

- a. catalytic cracking
- b. catalytic reforming
- c. combustion
- d. calorimetry

Explanation: Catalytic cracking can provide shorter carbon chains from longer carbon chains in a specific, efficient manner.

---

20. The process in which a hydrocarbon fuel can be further branched to increase fuel efficiency is called...

- a. cracking
- b. reforming
- c. combustion
- d. calorimetry

Explanation: Hydrocarbon reforming can be used to branch a hydrocarbon fuel.

Remember to bubble in ALL your answers BEFORE time is called. Double check your name, uteid, and version number before you turn in your bubblesheet. You must keep your exam for future reference. Please do not lose it. We will not replace it.